As the root absorbs water the pressure upon the column of mercury increases, causing it to rise in the tube, lifting the cork and indicator with it. The indicator then marks a continuous spiral course on the cylinder. As the cylinder revolves once each hour the hourly variation can be studied by observing the distance between the lines.

The supply of water given to the plant is kept constant by means of a flask of water supported by a stand and having an exit tube touching the surface of the water in the dish in which is placed the jar containing the plant.

The apparatus can be made in sizes appropriate for the study of periodicity of root pressure in almost any plant.

An eight day clock should be used and the apparatus need scarcely be touched until the plant is exhausted. The difference between the maximum and minimum variation will grow less as the column of mercury becomes higher but the time of variations will be the same for each day.

The apparatus described may be constructed at a very small expense and used either for laboratory experiments or lecture room demonstration. Many new and interesting problems have arisen during the investigations with this instrument and it is hoped they can be arranged for presentation in the near future.

The record on the cylinder of the apparatus shown in plate XV was made by a tomato plant. The experiment was started at 9 A. M., that being the time represented by the bottom line on the cylinder. The apparatus is represented otherwise as at the beginning of an experiment.

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On the apical growth of the stem and the development of the sporangium of Botrychium Virginianum.

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(WITH PLATE XVI.)

The origin and affinities of the Filicineæ is one of the most important problems of systematic botany. Among investigations directed to solving this problem not least have been those concerning the origin of the Filices and the relations of the eusporangiate and leptosporangiate groups. It has been advocated by some that the Ophioglosseæ form a natural series, running from Ophioglossum to Botrychium Virginianum; the latter being closely related to Osmunda and through it, as the connecting link, with the Filices, forming the complete phylogeny of the Filicīneæ. With this in view it was thought that if the development and mode of growth of the meristems of Botrychium Virginianum were known, it would possibly show more closely its relations to Osmunda and help to clearer views concerning the position of the eusporangiate ferns.

Dr. Douglas H. Campbell in a comparative study of the roots of Osmunda and Botrychium[1] shows that the roots grow from a clearly defined apical cell in the form of a three-sided pyramid. From the general fact that a fern grows from the same shaped cell in all parts, roots, stem and leaf, it would be expected that a cell of similar form would appear in the stem of this same plant (fig. 1). It is slightly longer than that of the root, but has unmistakably the form of a three-sided pyramid. In the stem figured the nucleus also appears in a state of division. Unless growing very slowly the segments retain their distinctness for a considerable time, often the outline of as many as three or four being easily traceable (fig. 2); while the segments follow the general rules of segmentation and divide by a transverse wall slightly below the center of the cell. The lower part may then divide into several cells by transverse and longitudinal walls; and the upper part first by a longitudinal wall into two, then each of these into two or more, thus after a time confusing the limits of each segment.

Turning now to the sporangium, we find that in the Filices proper the sporangium always arises from a single epidermal cell, which usually, according to Bower[2], projects more or less strongly beyond the surrounding tissue before segmentation begins; then a transverse wall cuts off a lower cell from which the stalk develops, and from the upper one the sporangium proper, or head of the sporangium, arises.

In Botrychium this distinction cannot be made. The sporangium is first noticed as a cell of large size (fig. 3) on the side of the pinnule in section, but not protruding beyond the other cells. The nucleus in the specimen figured, from its comparatively large size and appearance, seemed ready to divide.

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[1] Notes on the apical growth of Osmunda and Botrychium, BOTANICAL GAZETTE, Feb. 1891.

[2] BOWER: The comparative examination of the meristems of ferns as a phylogenetic study; Annals of Botany, III. 362.

Three oblique walls are formed one after another, thus giving rise to a three sided apical cell. The sporangium now projects slightly (fig. 4), and in the figure probably two segments have been cut off and will be devoted to forming the stalk of the sporangium. While it is true that the sporangium arises from a group of cells, and probably some cells other than those heavily shaded (in fig. 4 those cut off from the original cell) take part in the formation of the sporangium, yet it seems equally probable that the entire sporangium can be referred to the single large cell (fig. 3). If this be true, a closer connection is shown with the leptosporangiate group than has been generally supposed. In Osmunda[3] the sporangium is not always referable to a single cell in its origin, but almost always one is noticeable as the initial cell of the young sporangium, which does not project before segmentation occurs. After the formation of the apical cell the sporangium grows to a considerable size by direct segmentation before any change is apparent. There now becomes prominent the change of the apical cell from a tetrahedral to a cubical form, from a T-division (fig. 5). Three cells, from their general shape, are evidently those which previously formed the single large tetrahedral cell. The sporangium is now probably half grown and the cell from which the archesporium and tapetum develop should make its appearance; but from the great bulk of the sporangium it would escape notice, unless it had a very large nucleus. Not until the primary cell has undergone several divisions are the archesporium cells noticeable (fig. 5). In the sporangium figured there were six of these, all very prominent from the large nuclei in them. These cells divide very rapidly, and cause the body of the sporangium to enlarge, making the distinction of body and stalk noticeable (fig. 6). The stalk is seen to be very short and thick, and the tapetum layer also makes its appearance, consisting of approximately two layers of cells. Even the oblong cell which retained the place of the initial, after the division of the tetrahedral cell, is now no longer distinguishable, each cell dividing as rapidly as possible and the whole sporangium enlarging equally in all parts. It is during the rapid division of the archesporium cells that a very interesting and previously unnoted (?) occurrence was observed, namely the simultaneous division of *all* the archesporium cells in one sporangium. In one (fig. 7) all nuclei were

[3] L. c., p. 362.

in the so-called spindle stage of division, with probably forty to fifty cells in the sporangium. Another stage (fig. 8) showed the division nearly completed, while four or five other sporangia showed their nuclei in various other stages of division.

It appears evident that the origin of the archesporium in Botrychium is more deeply seated in the tissue than it is in the Filices. This, with other characteristics of complexity of structure, according to the generally accepted view, places the Ophioglosseæ in origin as the most recent forms, in opposition to the more primitive Filices. However, it seems probable that the Filices have been a degenerating group, becoming more and more simple according to the nature of their surroundings, and thus necessarily giving rise to new forms; while the Ophioglosseæ retained their complexity and suffered no change, giving them thus the position of the more primitive forms. This we see is supported by Bower[4] with geological evidence.

The material used was fixed in one per cent. chromic acid, stained in aqueous alum-carmine, and after dehydrating, passing through turpentine and imbedding in paraffin, was sectioned on a Minot microtome; then stained on the slide with seventy per cent. alcoholic bismarck-brown to sharply differentiate the cell walls.

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Explanation of Plate XVI.—Fig. 1. Young stem of Botrychium Virginianum showing the apical cell dividing; four segments shown. × 225.—Fig. 2. Pinnule; apical growth; outlines of three segments shaded. × 225.—Fig. 3. Portion of longitudinal section of pinnule showing origin of sporangium (large cell) × 450.—Fig. 4. Sporangium after apical cell is formed, two segments having been cut off. × 325.—Fig. 5. Sporangium in an advanced state of growth, two of the six archesporium cells shown; also the disappearance of the tetrahedral apical cell by a T-division. × 325.—Fig. 6. Sporangium nearly full grown; *t*, tapetal layer. × 170.—Figs. 7 and 8. Archesporium cells dividing, tapetal layer of two layers of cells surrounding them. × 325.

[4] Bower: Is the eusporangiate or the leptosporangiate the more primitive type in the ferns? Annals of Botany, vol. V. no. xviii.